Foundations of Modern Networking

SDN, NFV, QoE, IoT, and Cloud

By: William Stallings

Chapter 13

Cloud Computing

SDN and NFV

- Cloud computing predates software-defined networking (SDN) and network function virtualization (NFV)
- SDN offers a centralized command and control of network resources and traffic patterns
  - A single central controller, or a few distributed cooperating controllers, can configure and manage virtual networks and provide QoS and security services
  - This relieves network management of the need to individually configure and program each networking device
- NFV offers automated provisioning of devices
  - NFV virtualizes network devices, such as switches and firewalls, as well as compute and storage devices, and provides tools for scaling out and automatically deploying devices as needed
  - Therefore, each project or cloud customer does not require separate equipment or reprogramming of existing equipment
  - Relevant devices can be centrally deployed via a hypervisor management platform and configured with rules and policies

Service Provider Perspective

- The provider needs to be able to rapidly manage the entire network to handle traffic bottlenecks, manage numerous traffic flows with differing QoS requirements, and deal with outages and other problems
  - SDN can provide the needed overall view of the entire network and secure, centralized management of the network
- The provider needs to be able to deploy and scale in/out and up/down virtual switches, servers, and storage rapidly and transparently for the customer
  - NFV provides the automated tools for managing this process

Private Cloud Perspective

- Large and medium-size enterprises see a number of advantages to moving much of their network-based operations to a private cloud or a hybrid cloud
- As the overall resource demand grows, the ability to deploy and manage all of the equipment becomes more challenging
- Further complicating the scenario is the need for load balancing as projects grow
- The need for automated provisioning of virtual networking equipment almost becomes a requirement, and with all the new virtual devices, centralized command and control becomes a must
- SDN and NFV provide the enterprise with the tools to successfully develop and manage private cloud resources for internal use

End of Chapter 13

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Chapter 14

The Internet of Things: Components

The IoT Era Begins

- The future Internet will involve large numbers of objects that use standard communications architectures to provide services to end users
- It is envisioned that tens of billions of such devices will be interconnected in a few years
- This will provide new interactions between the physical world and computing, digital content, analysis, applications, and services
- This resulting networking paradigm is being called the Internet of Things (IoT)

IoT Era

- Technology development is occurring in many areas
- Many proposals and products have been developed for low power protocols, security and privacy, addressing, low cost radios, energy efficient schemes for long battery life, and reliability for networks of unreliable and intermittently sleeping nodes
  - These wireless developments are crucial for the growth of IoT
- In addition, areas of development have also involved giving IoT devices social networking capabilities

The Scope of the Internet of Things

Internet of Things (IoT)

- A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies

Thing

- With regard to the IoT, this is an object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks

Device

- With regard to the IoT, this is a piece of equipment with the mandatory capabilities of sensing, actuation, data capture, data storage, and data processing

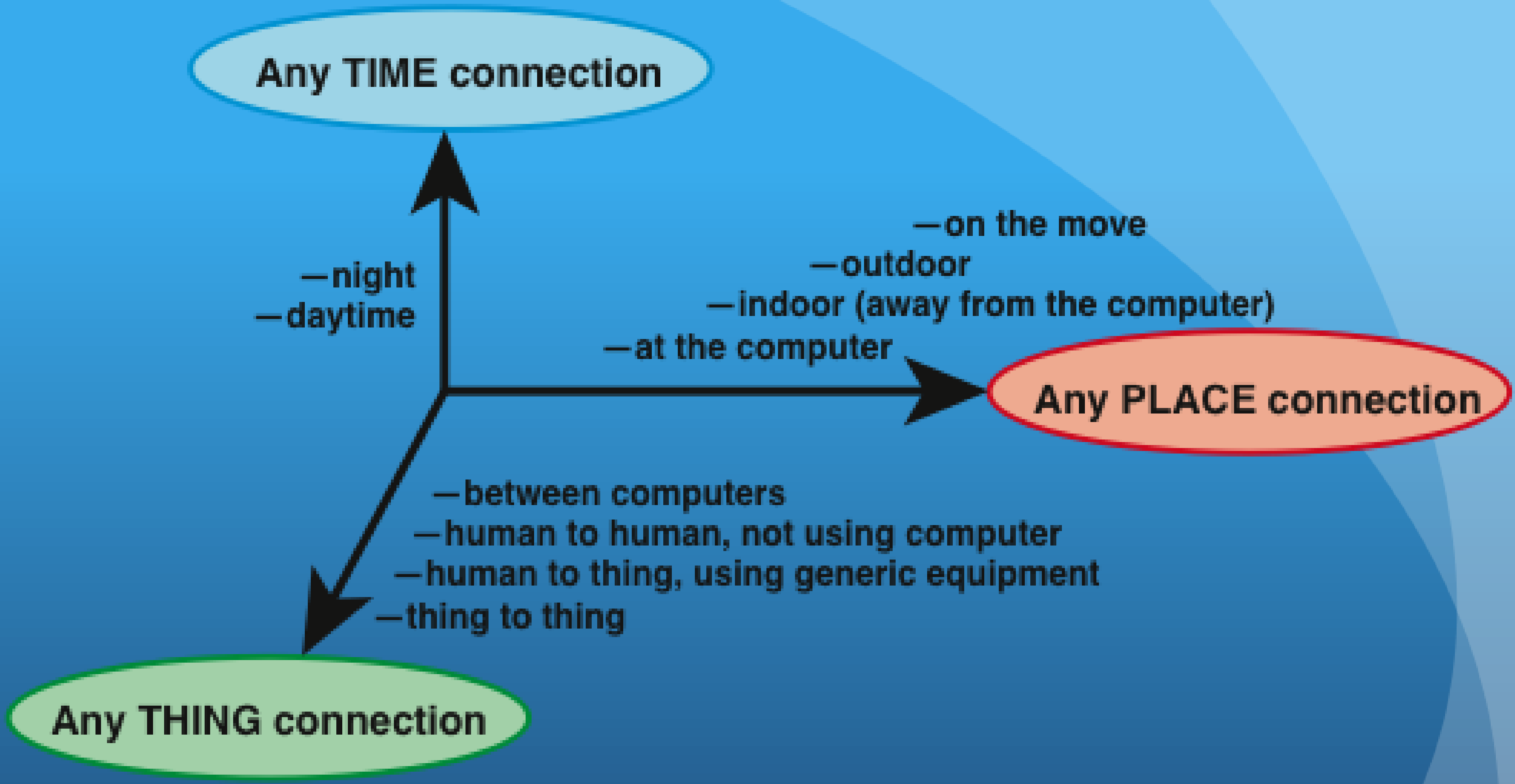

Figure 14.1 The New Dimension Introduced in the Internet of Things

The Scope of the Internet of Things

- Physical objects + Controllers, Sensors, Actuators + Internet = IoT
- An instance of the IoT consists of a collection of physical objects, each of which:
  - Contains a microcontroller that provides intelligence
  - Contains a sensor that measures some physical parameter/actuator that acts on some physical parameter
  - Provides a means of communicating via the Internet or some other network
- The collection of smart objects at a site, plus any other local compute and storage device, can be characterized as a network or an Internet of Things

Table 14.1 The Internet of Things

Service Sectors	Application Groups	Locations	Example Devices
IT & Networks	Public	Services, e-commerce, data centers, mobile carriers, fixed carriers ISPs	Servers, storage, PCs, routers, switches, PBXs
	Enterprise	IT/data center, office, private nets	
Security/public safety	Surveillance equipment, tracking	Radar/satellite, military security, unmanned, weapons, vehicles, ships, aircraft, gear	Tanks, fighter jets, battlefield comms, jeeps
	Public infrastructure	Human, animal, postal, food/health, packaging, baggage, water treatment, building environmental, general environmental	Cars, breakdown lane worker, homeland security, fire, environmental monitor
	Emergency services	Equipment and personnel, police, fire, regulatory	Ambulances, public security vehicles
Retail	Specialty	Fuel stations, gaming, bowling, cinema, discos, special events	POS terminals, tags, cash registers, vending machines, signs
	Hospitality	Hotels, restaurants, bars, cafes, clubs	
	Stores	Supermarkets, shopping centers, single site, distribution center	
Transportation	Non-vehicular	Air, rail, marine	Vehicles, lights, ships, planes, signage, tolls
	Vehicles	Consumer, commercial, construction, off-road	
	Transportation systems	Tolls, traffic management, navigation	

Industrial	Distribution	Pipelines, materials handling, conveyance	Pumps, valves, vats, conveyers, pipelines, motors, drives, converting, fabrication, assembly/packing, vessels, tanks
	Converting, discrete	Metals, paper, rubber, plastic, metalworking, electronics assembly, test	
	Fluid/processes	Petro-chemical, hydrocarbon, food, beverage	
	Resource automation	Mining, irrigation, agricultural, woodland	
Healthcare and Life Science	Care	Hospital, ER, mobile PoC, clinic, labs, doctor office	MRIs, PDAs, implants, surgical equipment, pumps, monitors, telemedicine
	In-vivo, home	Implants, home monitoring systems	
	Research	Drug discovery, diagnostics, labs	
Consumer & home	Infrastructure	Wiring, network access, energy mgt	Digital camera, power systems, dishwashers, eReaders, desktop computers, washer/dryer, meters, lights, TVs, MP3, games console, lighting, alarms
	Awareness & safety	Security/alert, fire safety, environmental safety, elderly, children, power protection	
	Convenience & entertainment	HVAC/climate, lighting, appliance, entertainment	
Energy	Supply/demand	Power gen, trans & dist, low voltage, power quality, energy mgt	Turbines, windmills, UPS, batteries, generators, meters, drills, fuel cells
	Alternative	Solar, wind, co-generation, electro-chemical	
	Oil/gas	Rigs, derricks, well heads, pumps, pipelines	
Buildings	Commercial, institutional	Office, education, retail, hospitality, healthcare, airports, stadiums	HVAC, transport, fire & safety, lighting, security, access
	Industrial	Process, clean room, campus	

Source: Beecham Research

Components of IoT-Enabled Things

- The key ingredients of an IoT-enabled thing are:
  - Sensors
  - Actuators
  - A microcontroller
  - A means of communication (transceiver)
  - A means of identification (radio-frequency identification [RFID])
- A means of communication is an essential ingredient, otherwise, the device cannot participate in a network
- Nearly all IoT-enabled things have some sort of computing capability
- A device may have one or more of the other ingredients

Category	What it Does	Example Devices
Position measuring devices	Designed to detect and respond to changes in angular position or in linear position of the device	Potentiometer, Linear Position Sensor, Hall Effect Position Sensor, Magnetoresistive Angular, Encoders (Quadrature, Incremental Rotary, Absolute Rotary, Optical)
Proximity, motion sensors	Designed to detect and respond to movement outside of the component but within the range of the sensor	Ultrasonic Proximity, Optical Reflective, Optical Slotted, PIR (Passive Infrared), Inductive Proximity, Capacitive Proximity, Reed Switch, Tactile Switch
Inertial Devices	Designed to detect and respond to changes in the physical movement of the sensor	Accelerometer, Potentiometer, Inclinometer, Gyroscope, Vibration Sensor/Switch, Tilt Sensor, Piezo Shock Sensor, LVDT/RVDT
Pressure/Force	Designed to detect a force being exerted against it	IC Barometer, Strain Gauge, Pressure potentiometer, LVDT, Silicon transducer, Piezoresistive sensor, Capacitive transducer
Optical Devices	Designed to detect the presence of light or a change in the amount of light on the sensor	LDR, Photodiodes, Phototransistors, Photo interrupters, Reflective Sensors, IrDA Transceiver, Solar Cells, LTV (Light Voltage) Sensors
Image, Camera Devices	Designed to detect and change a viewable image into a digital signal	CMOS Image Sensor
Magnetic Devices	Designed to detect and respond to the presence of a magnetic field	Hall Effect Sensor, Magnetic Switch, Linear Compass IC, Reed Sensor
Media Devices	Designed to detect and respond to the presence or the amount of a physical substance on the sensor	Gas, Smoke, Humidity, Moisture, Dust, Float Level, Fluid Flow
Current and Voltage Devices	Designed to detect and respond to changes in the flow of electricity in a wire or circuit	Hall Effect current sensor, DC current sensor, AC current sensor, Voltage Transducer
Temperature	Designed to detect the amount of heat using different techniques and in different mediums	Thermistor NTC, Thermistor PTC, Resistance Temp Detectors (RTD), Thermocouple, Thermopile, Digital IC, Analog IC, Infrared Thermometer/Pyrometer
Specialized	Designed to provide detection, measurement, or response in specialized situations, which also may include multiple functions	Audio Microphone, Geiger-Mu¨ller Tube, Chemical

Table 14.2

Types of Sensors

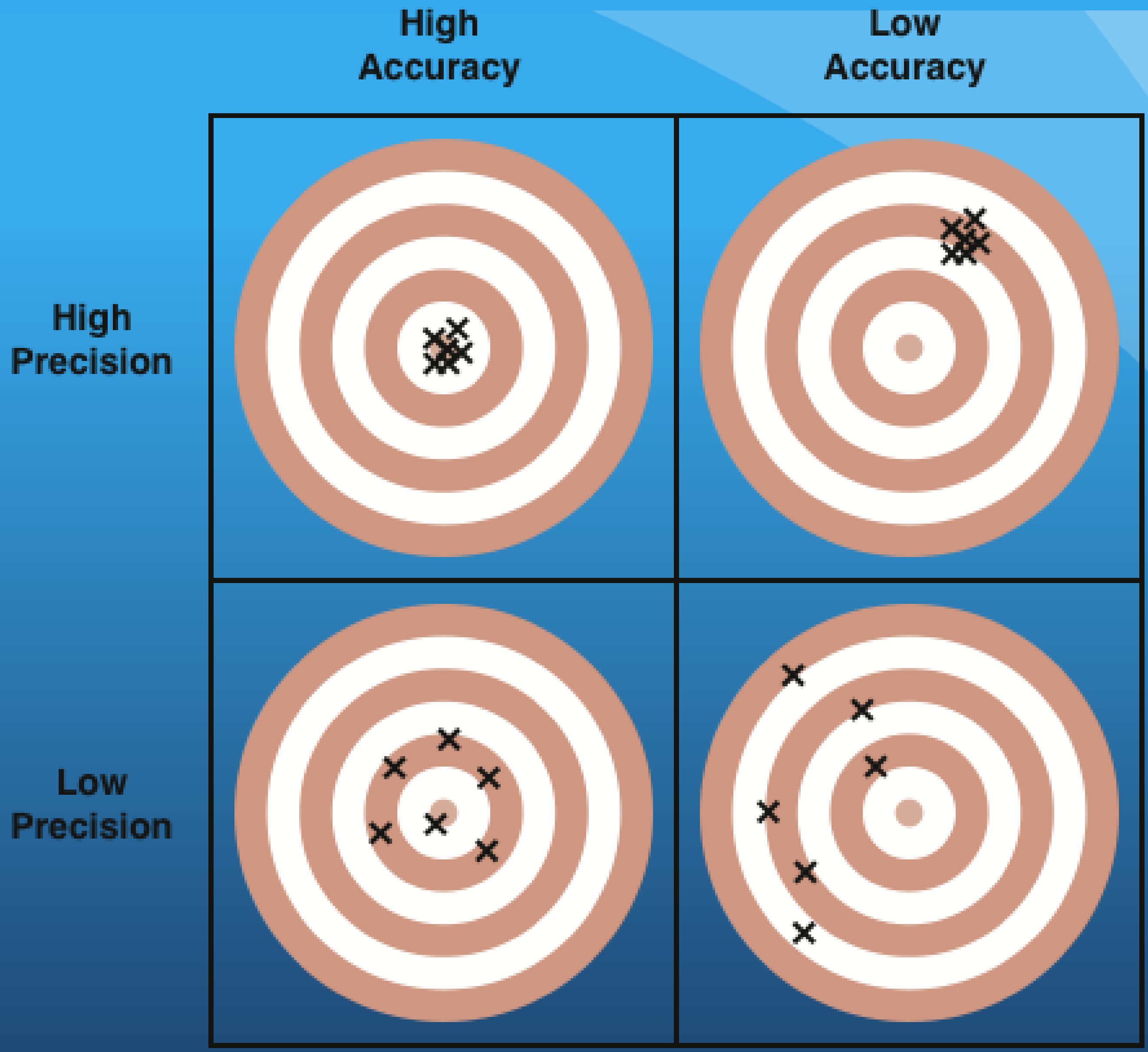

Figure 14.3 Precision and Accuracy

Actuators

- An actuator receives an electronic signal from a controller and responds by interacting with its environment to produce an effect on some parameter of a physical, chemical, or biological entity
- Actuators are generally classified as:
  - Hydraulic
    - Hydraulic actuators consist of a cylinder or fluid motor that utilizes hydraulic power to facilitate mechanical process
    - The mechanical motion gives an output in terms of linear, rotary, or oscillatory motion
  - Pneumatic
    - Pneumatic actuators work on the same concept as hydraulic actuators except compressed gas is used instead of liquid
    - Energy, in the form of compressed gas, is converted into linear or rotary motion, depending on the type of actuator
  - Electric
    - Electric actuators are devices powered by motors that convert electrical energy to mechanical torque
  - Mechanical
    - Function through converting rotary motion to linear motion
    - Devices such as gears, rails, pulley, chain, and others are used to help convert the motion

Application Processors versus Dedicated Processors

- Application processors are defined by the processor's ability to execute complex operating systems
  - Thus, the application processor is general-purpose in nature
  - A good example of the use of an embedded application processor is the smartphone
- A dedicated processor is dedicated to one or a small number of specific tasks required by the host device
  - Because such an embedded system is dedicated to a specific task or tasks, the processor and associated components can be engineered to reduce size and cost

Deeply Embedded Systems

- Are a subset of embedded systems
- Use a microcontroller rather than a microprocessor, is not programmable once the program logic for the device has been burned into ROM, and has no interaction with a user
- Are dedicated, single-purpose devices that detect something in the environment, perform a basic level of processing, and then do something with the results
- Often have wireless capability and appear in networked configurations such as networks of sensors deployed over a large area
- The Internet of Things depends heavily on deeply embedded systems
- Typically, deeply embedded systems have extreme resource constraints in terms of memory, processor size, time, and power consumption

Radio-Frequency Identification (RFID)

- Uses radio waves to identify items
- Is increasingly becoming an enabling technology for IoT
- The main elements of an RFID system are tags and readers
  - RFID tags are small programmable devices used for object, animal and human tracking
    - They come in a variety of shapes, sizes, functionalities, and costs
  - RFID readers acquire and sometimes rewrite information stored on RFID tags that come within operating range
    - Readers are usually connected to a computer system that records and formats the acquired information for further uses

Applications

- The range of applications of RFID is wide and ever expanding

Four major categories of application are:

Tracking and identification

- Is the most widespread use

Payment and stored-value systems

- Electronic toll systems on highways and the use of electronic key fobs for payment at retail stores are examples

Access control

- Used for building access at many companies and universities

Anticounterfeiting

- Casinos use RFID tags on chips to prevent the use of counterfeit chips and the prescription drug industry uses RFID tags to ensure the pedigree of drugs as they move through the supply chain and also to detect theft

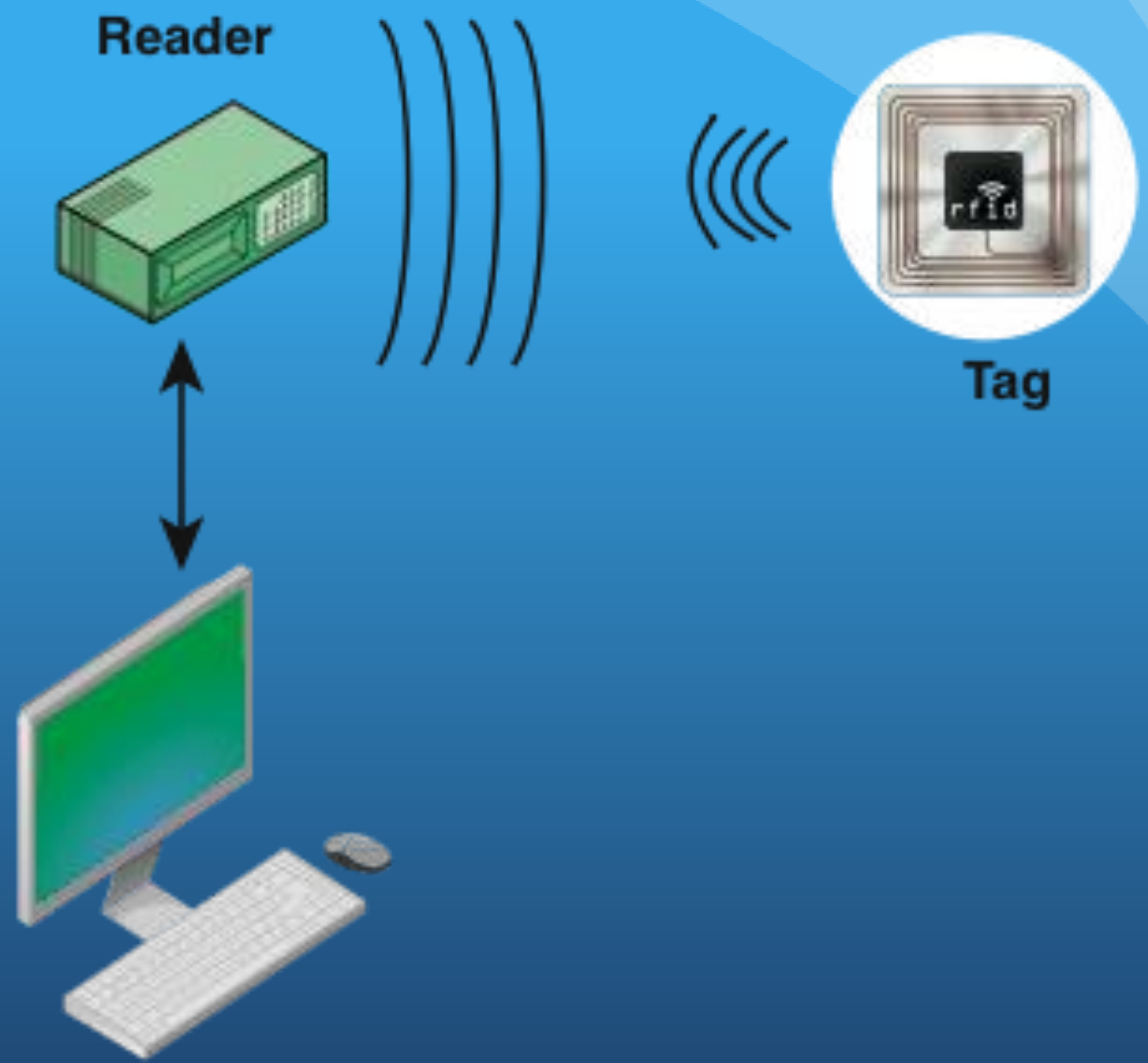

Figure 14.8 Elements of an RFID System

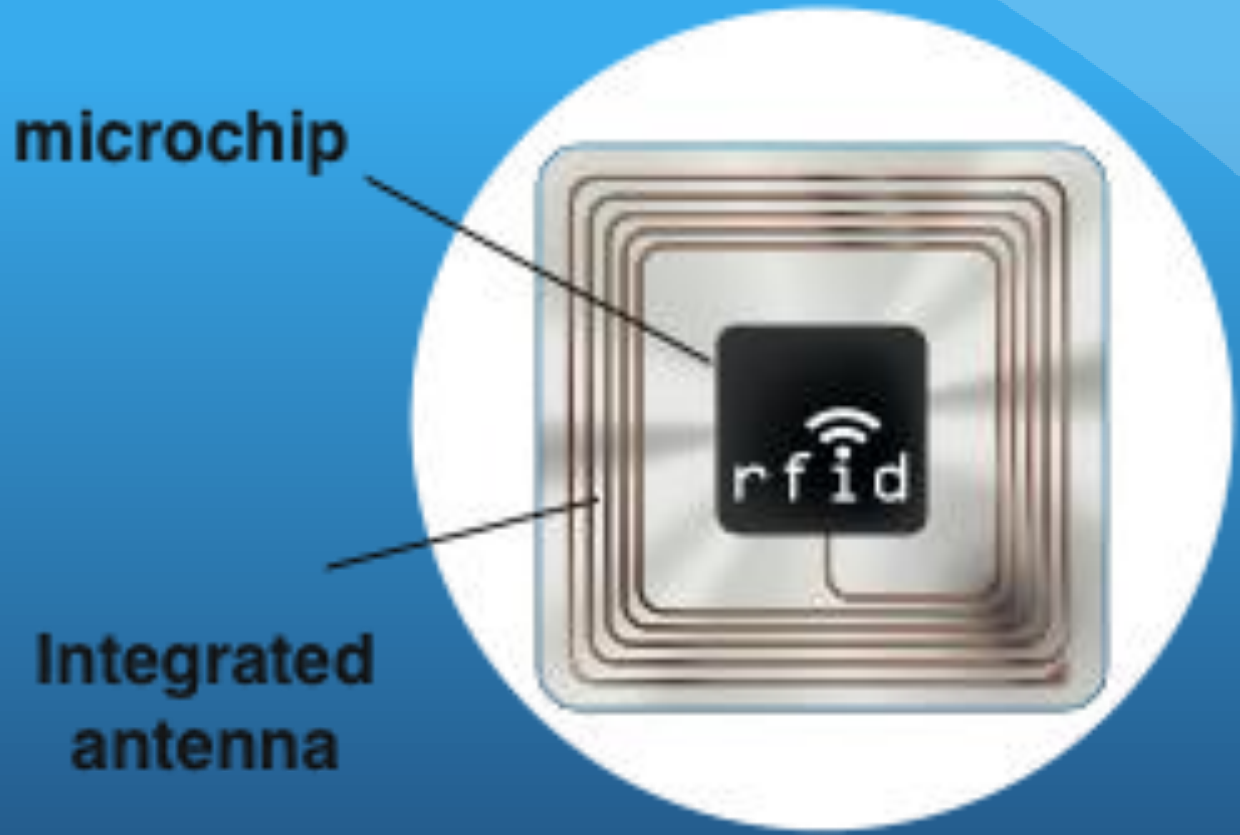

Figure 14.9 RFID Tag

Table 14.3 Types of Tags

	Passive	Semi-Passive	Active
Power source	Harvesting RF energy	Battery	Battery
Required signal strength from reader to tag	High	Low	Low
Communication	Response only	Response only	Respond or initiate
Max range	10 m	> 100 m	> 100 m
Relative cost	Least expensive	More expensive	Most expensive
Example applications	EPC Proximity cards	Electronic tolls Pallet tracking	Large-asset tracking Livestock tracking

Readers

- RFID readers communicate with tags through an RF channel
- The reader may obtain simple identification information or a more complex set of parameters
- In general, there are three categories of readers:
  - Fixed
    - Fixed readers create portals for automated reading of tags as they pass by
  - Mobile
    - Mobile readers are hand-held devices with an RFID antenna and reader and some computing capability
  - Desktop
    - This type of reader is typically attached to a PC or point-of-sale terminal and provides easy input

Table 14.4 Common RFID Operating Frequencies

Frequency Range	Frequencies	Passive Read Distance
Low Frequency (LF)	120-140 KHz	10-20 cm
High Frequency (HF)	13.56 MHz	10-20 cm
Ultra-High Frequency (UHF)	868-928 MHz	3 meters
Microwave	2.45 & 5.8 GHz	3 meters
Ultra-Wide Band (UWB)	3.1-10.6 GHz	10 meters

Table 14.5 Tag Functionality Classes

Class 0	UHFl read-only, preprogrammed passive tag
Class 1	UHF or HF; write once, read many (WORM)
Class 2	Passive read-write tags that can be written to at any point in the supply chain
Class 3	Read-write with onboard sensors capable of recording parameters like temperature, pressure, and motion; can be semipassive or active
Class 4	Read-write active tags with integrated transmitters; can communicate with other tags and readers
Class 5	Similar to Class 4 tags but with additional functionality; can provide power to other tags and communicate with devices other than readers

End of Chapter 14